1.0 INTRODUCTION

This report presents the Feasibility Study (FS) for the Portland Harbor Superfund Site in Portland, Oregon (**Figure 1-1**). Portland Harbor was evaluated and proposed for inclusion on the National Priorities List (NPL) pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), 42 U.S.C. §9605, by the U.S. Environmental Protection Agency (EPA) and formally listed as a Superfund Site in December 2000. The lead agency for this site is EPA.

The basis of this FS is environmental data collected and compiled by the Lower Willamette Group (LWG) and other parties since the inception of the Portland Harbor Remedial Investigation and Feasibility Study (RI/FS) in 2001[1]. The LWG is performing the remedial investigation (RI) and FS for the Portland Harbor Superfund Site (Site) pursuant to an EPA Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (AOC; EPA 2001, 2003, 2006). Oversight of LWG's Portland Harbor RI and FS is being provided by EPA with support from Oregon Department of Environmental Quality (DEQ). EPA has entered into a Memorandum of Understanding (MOU) with DEQ, six federally recognized tribes, two other federal agencies, and one other state agency[2], who have all participated in providing support in the development of this document.

The RI (insert citation) has been completed and has characterized the Site sufficiently to define the nature and extent of the source material and the Site-related contaminants. Baseline ecological and human health risk assessments (Windward 2013; Kennedy Jenks 2013) have also been completed. The site characterization and baseline risk assessments are sufficient to complete the FS for the Site.[3]

This FS focuses on approximately ten miles of the lower Willamette River from River Mile (RM) 1.9 (at the upriver end of the Port of Portland's Terminal 5) to RM 11.8 (near the Broadway Bridge), sometimes referred to as the "site" in this FS for convenience. The terms site, harbor-wide, and site-wide used in this FS generally refer to the sediments, pore water, and surface water within this reach of the lower Willamette River, not to the upland portions of the Portland Harbor Superfund Site.

[1] Upland source control efforts, including site-specific upland source control studies and implementation of source control measures, are performed under the oversight of the Oregon Department of Environmental Quality and are not within the scope of the Agreement and Order on Consent and Statement of Work for the in-water portion of the Site.

[2] Government parties that signed the MOU include: the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Grand Ronde Community of Oregon, the Confederated Tribes of Siletz Indians, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, the National Oceanic and Atmospheric Administration, the U.S. Department of the Interior, and the Oregon Department of Fish and Wildlife.

[3] Although this section identifies many specific sources of contamination, neither this section nor this report generally is intended as an exhaustive list of current or historical sources of contamination.

This FS is consistent with CERCLA, as amended (42 United States Code [U.S.C.] 9601 et seq.), and its regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] Part 300), commonly referred to as the National Contingency Plan (NCP) and was prepared in accordance with EPA guidance. Guidance documents used in preparing this FS include:

- *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988)
- *Clarification of the Role of Applicable or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA* (EPA 1997a)
- *Rules of Thumb for Superfund Remedy Selection* (EPA 1997b)
- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA 2002)
- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005)
- *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000)
- *Technical Resource Document on Monitored Natural Recovery* (EPA 2014)

1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of the FS is to identify, develop, screen, and evaluate a range of remedial alternatives to reduce risks from contaminated media to acceptable levels and to provide the regulatory agencies with sufficient information to select a remedy that meets the requirements established in the NCP. This FS report is comprised of four sections as described below.

- Section 1 – Introduction: Provides a summary of the Site RI, including Site description, Site history, nature and extent of contamination, contaminant fate and transport, and baseline human health and ecological risks.
- Section 2 - Identification and Screening of Technologies: Develops remedial action objectives (RAOs), develops preliminary remediation goals (PRGs) for addressing human health and ecological risks posed by contaminants in sediment and tissue, develops general response actions (GRAs) for each medium of interest, identifies areas of media to which general response actions might be applied, identifies and screens remedial technologies and process options, and

identifies and evaluates technology process options to select a representative process for each technology type retained for consideration.

- Section 3 - Development and Screening of Alternatives: Presents a range of remedial alternatives developed by combining the feasible technologies and process options. The alternatives are then refined and screened to reduce the number of alternatives that will be analyzed in detail. This screening aids in streamlining the feasibility study process while ensuring that the most promising alternatives are being considered.

- Section 4 - Detailed Analysis of Alternatives: Provides the detailed analysis of each alternative with respect to the following seven criteria: 1) overall protection of human health and the environment, 2) compliance with ARARs, 3) long-term effectiveness and permanence, 4) reduction of toxicity, mobility, or volume through treatment, 5) short-term effectiveness, 6) implementability, and 7) cost. In addition to the detailed analysis, a comparative analysis of remedial action alternatives is also presented in this section. EPA also recognizes that this site affects many stakeholders, including communities with environmental justice concerns who live along the river or who live elsewhere but use the river. The evaluation of remedial alternatives considers impacts to these communities.

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 miles north to its confluence with the Columbia River, and is one of 14 American Heritage Rivers in the country. It is the 19th largest river in the United States, and drains 11.7 percent of the State of Oregon. As Oregon's major port and population center, the lower Willamette River sees a great variety of uses including shipping, industrial, fishing, recreational, natural resource, and other uses. The lower reach of the Willamette River from RM 0 to approximately RM 26.5 is a wide, shallow, slow moving segment that is tidally influenced with tidal reversals occurring during low flow periods as far upstream as RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the lower Willamette River system. The lower reach has been extensively dredged to maintain a 40-foot deep navigation channel from RM 0 to RM 11.7.

The Portland Harbor RI/FS Study Area is located along the lower reach of the lower Willamette River in Portland, Oregon known as Portland Harbor (**Figure 1-1**). The RI/FS Study Area extends from RM 1.9 to 11.8 and up to a vertical elevation of 13.3 feet North American Vertical Datum of 1988 (NAVD88). While the harbor area is extensively industrialized, it occurs within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the lower Willamette River in the harbor includes marine terminals, manufacturing, and other commercial operations, as well as public facilities, parks, and open spaces. **Figures 1.2-1a** through

1.2-1d illustrate land use zoning within the lower Willamette River as well as waterfront land ownership. The State of Oregon owns certain submerged and submersible lands underlying navigable and tidally influenced waters. The ownership of submerged and submersible lands is complicated and has changed over time (**Figure 1.2-2**).

Today, the Willamette River is noticeably different from the river prior to industrial development that commenced in the mid to late 18th century. Historically, the Willamette River was wider with more sand bars and shoals and flow volumes were subject to greater fluctuation. The main river now has been redirected and channelized, several lakes and wetlands in the lower floodplain have been filled and agricultural lands converted to urban or industrial areas. The end result is a river that is deeper and narrower than it was historically with higher banks that prevent the river from expanding during high-flow events. The Willamette River channel, from the Broadway Bridge (RM 11.6) to the mouth (RM 0), currently varies in width from 600 to 1,900 feet. Further, the installation of a series of dams moderate fluctuations of flow in the lower Willamette River.

Little, if any, original shoreline or river bottom exists that has not been modified by the above actions, or as a result of them. Much of the shoreline has been raised, filled, stabilized, and/or engineered and contains overwater piers and berths, port terminals and slips, stormwater and industrial wastewater outfalls and combined sewer overflows (CSOs), and other engineered features. Constructed structures, such as wharfs, piers, floating docks, and pilings, are especially common in Portland Harbor where urbanization and industrialization are most prevalent. These structures are built largely to accommodate or support shipping traffic within the river and to stabilize the riverbanks for urban development. Constructed structures are clearly visible in the aerial photos provided in **Figures 1.2-3a** through **1.2-3n.**

Armoring to stabilize banks covers approximately half of the harbor shoreline, which is integral to the operation of activities that characterize Portland Harbor. Riprap is the most common bank-stabilization measure. However, upland bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to control periodic flooding as most of the original wetlands bordering the Willamette in the Portland Harbor area have been filled. Some riverbank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes.

A federal navigation channel, maintained to a depth of -40 feet with an authorized depth of -43 feet, extends from the confluence of the lower Willamette River with the Columbia River to RM 11.7 (**Figure 1.2-4**). The lower Willamette River federal navigation project was first authorized in 1878 to deepen and maintain parts of the Columbia River and lower Willamette River with a 20-foot minimum depth. The depth of the navigation channel has been deepened at various intervals since that time (i.e., increased to 25 feet in 1899, 30 feet in 1912, 35 feet in 1930, and 40 feet in 1962).

Container and other commercial vessels regularly transit the river. Certain parts of the river require periodic maintenance dredging to keep the navigation channel at its maintained depth. In addition, the Port of Portland and other private entities periodically perform maintenance dredging to support access to dock and wharf facilities. Dredging activity has greatly altered the physical and ecological environment of the river in Portland Harbor.

Development of the river has resulted in major modifications to the ecological function of the lower Willamette River. However, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that occur within and along the river. The river is also an important rearing site and pathway for migration of anadromous fishes, such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, are active within the lower Willamette River. A detailed description of ecological communities in Portland Harbor is presented in the Baseline Ecological Risk Assessment (BERA) provided as Appendix G of the RI Report.

1.2.2 Site History

Since the late 1800s, the Portland Harbor section of the lower Willamette River has been extensively modified to accommodate a vigorous shipping industry. Modifications include redirection and channelization of the main river, draining seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Historically, the Willamette was wider, had more sand bars and shoals, and fluctuated greatly in volume.

The lower Willamette River and its adjacent upland areas have been used for industrial, commercial, and shipping operations for over a century. Commercial and industrial development in Portland Harbor accelerated in the 1920s and again during World War II, which reinvigorated industry following the Great Depression. Before World War II, industrial development primarily included sawmills, manufactured gas production (MGP), bulk fuel terminals, and smaller industrial facilities. During World War II, a considerable number of ships were built at military shipyards located in Portland Harbor. Additional industrial operations located along the river in the post-World War II years included wood-treatment, agricultural chemical production, battery processing, ship loading and unloading, ship maintenance, repair and dismantling, chemical manufacturing and distribution, metal recycling, steel mills, smelters, foundries, electrical production, marine shipping and associated operations, rail yards, and rail car manufacturing. Many of these operations continue today. Contaminants associated with these operations were released from various sources and migrated to the lower Willamette River. The long history of industrial and shipping activities in the Portland Harbor, as well as agricultural, industrial, and municipal activities upstream of Portland Harbor, has contributed to chemical contamination of surface water and sediments in the lower Willamette River.

1.2.2.1 Investigation History

Many environmental investigations by private, state, and federal agencies have been conducted, both in the lower Willamette River and on adjacent upland properties, to characterize the nature and extent of contamination in the river, as well as to identify potential sources of contaminants that could continue to enter the river. Investigations have been conducted in Portland Harbor from the 1920s to the present, with most studies being performed from the late 1970s through the present. Nearly 700 documents and data sets were obtained that address conditions in the lower Willamette River. Specific historical and recent studies and data sets were selected for inclusion in the data set used to characterize and evaluate the Study Area in the RI and FS reports.

Site data were collected by the LWG during four major rounds of field investigations between 2001 and 2010 to complete the RI. The investigations were often timed around varying river stages, river flows, and storm events. The field investigations first began in 2001 in the Initial Study Area (ISA) as defined by the AOC, Statement of Work (SOW), and Programmatic Work Plan as RM 3 to RM 9. As the studies commenced, the Study Area was expanded from RM 1.9 to RM 11.8, as well as a portion of the Multnomah Channel. Studies conducted by the LWG also included areas downriver of the Study Area to the confluence with the Columbia River at RM 0 and upriver to RM 28.4. Surface and subsurface sediment samples, sediment trap samples, riverbank sediment and soil samples, surface water samples, stormwater and stormwater solids samples, groundwater samples, transition zone water (TZW) samples, and biota/tissue samples were collected and analyzed during the various investigations conducted.

1.2.2.2 Upland Source Control Measures

Identifying current sources of contamination to the Study Area and eliminating or minimizing these pathways where possible is critical for remedy effectiveness as well as evaluating the recontamination potential of a cleanup. In February 2001, DEQ, EPA, and other governmental parties signed an MOU agreeing that DEQ, using state cleanup authority, has lead technical and legal responsibility for identifying and controlling upland sources of contamination that may impact the river (e.g., sediment, groundwater, TZW, and/or surface water). Currently, DEQ is investigating or directing source control work at over 90 upland sites in Portland Harbor and evaluating investigation and remediation information at more than 80 other upland sites in the vicinity (ODEQ 2014). Additionally, DEQ is working with the City of Portland under an Intergovernmental Agreement to identify and control upland sources draining to the Study Area through 39 city outfalls, and with the Oregon Department of Transportation on controlling sources in highway and bridge runoff drained to the Study Area (City of Portland 2012).

The City prepared a CSO Management Plan (City of Portland 2005) with recommendations to address wet weather overflow discharges, including implementation of storage and treatment facilities along the Willamette River ("Big Pipe project") to control the CSO discharges. The primary means for increasing the

storage capacity was through construction of the West Side Tunnel (completed in 2006) and the East Side Tunnel (completed in 2011).

The cleanup of known or potentially contaminated upland sites is tracked in DEQ's Environmental Cleanup Site Information (ECSI) database, which is available online at http://www.deq.state.or.us/lq/ECSI/ecsi.htm, and source control efforts are summarized in DEQ's Portland Harbor Upland Source Control Milestone and Summary Report (http://www.deq.state.or.us/lq/cu/nwr/PortlandHarbor/jointsource.htm).

Figures 1.2-5a through **1.2-5e** graphically display the status of DEQ source control evaluations as of 2014 for various sites along the Study Area by potential release/migration pathways to the river. An important overall assumption of the FS is that upland sources in Portland Harbor will be controlled sufficient to achieve project goals through the DEQ process.

1.2.2.3 Early Action Sites

Within Portland Harbor, separate orders have been executed by EPA with various parties for five specific sites. These sites are:

1. Terminal 4 – conducted by the Port of Portland
2. Gasco – conducted by NW Natural
3. Gasco and Siltronic – conducted by NW Natural and Siltronic
4. Arkema – conducted by Arkema
5. RM 11 E – conducted by Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland

These projects are currently in various stages of completion as described below.

- **Terminal 4** – The Port of Portland has been implementing a removal action at Terminal 4. A Phase I Abatement Measure was completed in 2008 that consisted of remediation and maintenance dredging of approximately 13,000 cubic yards of sediment. Remediation consisted of dredging 6,315 cubic yards of contaminated sediment and placing it in an off-site disposal facility, isolating contaminated sediment in the back of Slip 3 with a cap made of organoclay-sand mix, and stabilizing the bank along Wheeler Bay.

- **Gasco** – A removal action was conducted at the Gasco site between August and October 2005. Approximately 15,300 cubic yards of a tar-like material and tar-like contaminated sediment were removed by dredging from the riverbank and nearshore area adjacent to the Gasco facility and disposed of off-site. After the removal action, an organoclay mat was placed along an upper-elevation band of the shoreline dredge cut. This mat was secured with placement of an overlying

sand cap and quarry spalls. A one foot thick sand cap and 0.5 foot of erosion protection gravel was placed over the remainder of the removal area (0.4 acres). Approximately 0.5 foot of a "fringe cap" of sand material was placed over 2.3 acres of the area surrounding the removal area.

- **Gasco and Siltronic** – NW Natural and Siltronic are conducting site characterization and design evaluations for the area adjacent to their two facilities. Under the order, NW Natural and Siltronic have agreed to perform further characterization, studies, analysis and preliminary design that will lead ultimately to a final remedy at the Gasco Sediments Site. Conducting this work will facilitate construction of the final remedy to begin expeditiously following issuance of a Record of Decision (ROD) for the Portland Harbor Superfund Site. The remedial action for the NW Natural and Siltronic sediments will be implemented in coordination with and following completion of any necessary upland NW Natural and Siltronic source control work being managed by DEQ.

- **Arkema** – Under an AOC with EPA, Arkema conducted additional site characterization and preliminary design evaluations for a planned Removal Action.

- **River Mile 11 East -** A group of Respondents, collectively known as the RM 11E Group (includes Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland), entered into an AOC to perform supplemental RI/FS work in support of preliminary design activities.

In addition, a near-shore sediment removal adjacent to the BP Arco Bulk Terminal in 2007-08 under DEQ oversight resulted in 12,300 cubic yards of petroleum-contaminated soil and sediment being removed and disposed of off-site, and replaced with clean fill in conjunction with the installation of a new steel sheet-pile seawall along the entire riverbank of the BP Arco Bulk Terminal property.

1.2.3 Nature and Extent of Contamination

Due to the large number of contaminants detected at the Study Area in various media, the nature and extent of contamination focuses on specific contaminants or groups of contaminants selected by evaluating several criteria discussed in Section 5.1 of the RI.

Fourteen indicator contaminants were discussed in detail in Section 5 of the RI report based on frequency of detection, ease of cross media comparisons, co-location with other contaminants, widespread sources, and similar chemical structures and properties. Information regarding the remaining contaminants is provided in Appendix D of the RI. The nature and extent of indicator contaminants in sediment and surface water are summarized in the following sections. As discussed in Section 5.1 of the RI, additional contaminants beyond the indicator contaminants presented in the RI (and summarized in this section) are present at the site at concentrations that may pose unacceptable risk to human health and the environment. Section 2.2.1 of the FS identifies the

contaminants of concern (COCs) selected for the Portland Harbor Superfund Site and discusses the process for selecting the COCs.

Groundwater COCs are summarized in the subsections below because this information may affect decisions about sediment caps within the Site. The COCs in river banks are also summarized because EPA may include some bank areas above elevation 13.3 feet NAVD88 within the Portland Harbor Site based on future site-specific determinations.

1.2.3.1 Sources

Historical and current locations of various industrial facilities identified along the lower Willamette River are provided by industrial sector in **Figures 1.2-6a** through **1.2-6j**. The approximate location of facilities is shown on the maps; however, the actual extent of historical and current facilities/operations is not shown. Detailed information regarding historic and current sources of contamination in the lower Willamette River is provided in Section 4 of the RI Report.

Each of these industrial sectors is typically associated with the use of various chemicals. The contaminants are dependent upon the activities conducted, but the contaminants most commonly associated with each industry sector include the following:

Industrial Sector	Common Industry Contaminants
Ship Building, Dismantling, and Repair	Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), metals (e.g., Cu, Cr, Pb, Hg, Zn), phthalates, butyltins
Wood Products and Wood Treating	VOCs, SVOCs, TPH, benzene, PAHs, metals (e.g., As, Cr, Cu, Zn), pesticides, fungicides, biocides, borates, pentachlorophenol, creosote, acid/alkaline wastes, dioxins
Chemical Manufacturing and Distribution	Vary depending on the operations, but chemical manufacturing known to have occurred within Portland Harbor includes pesticides, herbicides, VOCs, SVOCs, dioxins/furans, metals, PCBs, solvents, acid/alkaline wastes, benzene, TPH, and PAHs
Metal Recycling, Production, and Fabrication	VOCs, SVOCs, TPH, PCBs, PAHs, heavy metals, asbestos, cyanide, phthalates, fuel and fuel additives, battery acid, oil and grease, lubricants, paint pigments or additives, ionizing radioactive isotopes, transmission and brake fluids, lead acid, antifreeze, benzene, chemical residue, heating oil, solvents
Manufactured Gas Production	VOCs including benzene, toluene, ethylbenzene, and xylenes (BTEX), SVOCs, PAHs, TPH, metals, and cyanide

Industrial Sector	Common Industry Contaminants
Electrical Production and Distribution	PCBs, TPH, and PAHs
Bulk Fuel Distribution and Storage, and Asphalt Manufacturing	VOCs (benzene), SVOCs, PAHs, TPH, metals, gasoline additives (methyl tert-butyl ether [MTBE], ethylene dibromide [EDB], ethylene dichloride [EDC])
Steel Mills, Smelters, and Foundries	Metals, TPH, PAHs, PCBs, fuel additives, chlorinated VOCs
Commodities Maritime Shipping and Associated Marine Operations	Spillage of raw materials during transport to and from vessels, butyltins, metals, TPH, fuel additives, chlorinated VOCs
Rail Yards	VOCs, SVOCs, TPH, PCBs, and heavy metals

Contaminants released during industry operations and/or other activities to the air, soil, groundwater, surface water, and/or impervious surfaces can potentially migrate to the lower Willamette River via the following pathways: direct discharge, overland transport, groundwater, riverbank erosion, atmospheric deposition, overwater activities, and upstream watershed.

One key migration pathway for contaminants from these various industries to migrate to the river was through direct discharge via numerous public and private outfalls, including storm drains and CSOs, which are located along both shores of the lower Willamette River in the metropolitan area. In the early 1900s, rivers in the United States were generally used as open sewers, which was also true for the Willamette (Carter 2006). The process water from a variety of industries, including slaughterhouses, chemical plants, electroplaters, paper mills, and food processors, was discharged directly into the river. In the 1950s, municipal conveyance systems included interceptors and associated facilities were installed to reduce the volume of untreated sewage discharging to the Willamette from the City of Portland and regulatory actions in the 1960s and 1970s, such as the Clean Water Act, gradually reduced the direct discharge of waste to the Willamette River.

Historical releases from upland or overwater activities within the Study Area likely contributed to the majority of the observed contaminant distribution in sediments within the Study Area. The majority of current contaminant pathways to the river (soil erosion, groundwater, and stormwater) from upland sources are a result of historical operational practices, spills, and other releases.

In addition, point and nonpoint discharges within the Willamette River Basin are potential sources of contamination in sediment, surface water, and biota in the Study Area. Contaminants in discharges and runoff from diverse land uses in the basin eventually enter the river upstream of the Study Area. Contaminant loading from

sediment transport and water from upstream areas throughout the last century also contributed to the conditions currently observed in the Study Area.

1.2.3.2 Sediment

Sediment samples were collected from the Study Area for consideration in the FS. Much of the sampling was conducted by the LWG under the terms of the AOC and consistent with EPA approved work plans. Sample locations were biased toward areas of known or suspected contamination based on existing information. Additional sampling was conducted both upstream and downstream of the Study Area. Summary statistics of surface and subsurface sediment results for the contaminants presented above are provided in **Table 1.2-1**. Generally, concentrations of the contaminants were greater in subsurface sediment samples relative to surface samples, confirming that historical inputs were greater than current inputs. However, there are noted areas within the Study Area where surface concentrations are greater than subsurface concentrations likely reflecting more recent releases and/or disturbance of bedded sediments.

PCBs

With few exceptions, the highest PCB concentrations in surface sediment are present in nearshore areas outside the navigation channel and proximal to currently known or suspected sources (**Figure 1.2-7a**). Similar spatial and concentration trends are observed for subsurface sediments (**Figure 1.2-7b**). Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical. Overall, surface sediment PCB concentrations in the Study Area are greater than those in the upriver (upstream of Ross Island) and downstream (main stem of the lower Willamette River downstream of RM 1.9 and Multnomah Channel) reaches.

Dioxins/Furans

Total polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) were detected at several locations along the eastern and western nearshore zones and in Swan Island Lagoon (**Figure 1.2-8a**). Limited surface PCDD/F data are available; thus, spatial resolution is somewhat limited, especially in the navigation channel. Total PCDD/F concentrations in the subsurface are generally greater than that observed in surface sediments (**Figure 1.2-8b**). The higher concentrations generally observed in subsurface sediment relative to concentrations in surface sediment are indicative of a primarily historical input of these contaminants to the Study Area.

DDx

The highest reported DDx[4] concentrations in surface sediments are present in localized areas in the western nearshore zones between RMs 6.3 and 7.5 (**Figure 1.2-9a**). DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical (**Figure 1.2-9b**). The concentrations of

[4] DDx is the sum of 2,4'- and 4,4'-dichloro-diphenyl-dichloroethane (DDD), 2,4'- and 4,4'-dichloro-diphenyl-dichloroethene (DDE), and 2,4'- and 4,4'-dichloro-diphenyl-trichloroethane (DDT).

DDx in surface sediments are greater in the Study Area than those in the upriver, downtown, Multnomah Channel, and downstream reaches.

Total PAHs
The highest reported concentrations of total PAHs in surface sediments generally occur in the western nearshore zone downstream of RM 6.8, and on the east side at approximately RM 4.5 (**Figure 1.2-10a**). Total PAH concentrations are generally higher in subsurface sediments within the Study Area as a whole, pointing to higher historical inputs to the Study Area (**Figure 1.2-10b**). Within the Study Area, total PAHs in sediment are generally dominated by high molecular weight PAHs (HPAHs). Surface sediments from the western nearshore zone appeared to exhibit higher proportions of low molecular weight PAHs (LPAHs) than sediments from the eastern nearshore zone and the navigation channel, but follow the general trend of HPAH dominance. Subsurface sediments generally exhibit similar PAH profiles to the surface sediments.

Bis(2-ethylhexyl) phthalate
The highest reported concentrations of bis(2-ethylhexyl) phthalate were observed in samples collected in surface and subsurface sediment from the eastern nearshore in Swan Island Lagoon, between RM 3.8 and 4.1, and in the International Terminals Slip (**Figures 1.2-11a and 1.2-11b)**.

Total Chlordanes
The highest reported concentrations of total chlordanes were observed along the western nearshore zone between approximately RM 7 and 9 (**Figure 1.2-12a**). Total chlordane concentrations are generally higher in subsurface sediments within the Site, pointing to higher historical inputs to the Site (**Figure 1.2-12b**).

Aldrin and Dieldrin
Aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin readily undergoes biotic and abiotic transformation to dieldrin. The highest reported concentrations of aldrin were observed in the western nearshore zone from RM 6.8 to RM 7 and from RM 8.6 to RM 8.8 (**Figures 1.2-13a)**. The highest reported surface concentrations of dieldrin were observed in Swan Island Lagoon and in the western nearshore zone from RM 8 to 9 (**Figure 1.2-14a**). Aldrin and dieldrin concentrations are higher in subsurface sediments than surface sediments within the Site (**Figures 1.2-13b and 1.2-14b**), pointing to higher historical inputs to the Study Area.

Metals
The highest reported arsenic concentrations were reported in several locations in the eastern nearshore at RM 2.3, RM 5.6, RM 7.2, near the mouth of Swan Island Lagoon, and in the western nearshore area at RM 6.8, RM 8.6, and RM 10.2 (**Figure 2.1-15a**). Arsenic concentrations are generally greater in the surface sediments than in subsurface sediments within the Study Area (**Figure 1.2-15b**).

The highest reported chromium concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4.4, RM 5.6-5.9, and in Swan Island Lagoon, and in the

western nearshore zone at RM 6-6.1, RM 6.8-6.9, and RM 8.8-9.2 (**Figure 2.1-16a**). Chromium concentrations are generally greater in the surface sediments than in subsurface sediments within the Study Area (**Figure 1.2-16b**).

The highest surface and subsurface copper concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4, RM 5.5-6.1, RM 11.1-11.3, and Swan Island Lagoon, and in the western nearshore zone from RM 4.3 through 10.4 (**Figure 1.2-17a**). Copper concentrations are generally similar in surface and subsurface sediments in the Study Area (**Figure 2.1-17b**).

The highest surface sediment zinc concentrations were found in the eastern nearshore zone at RM 4-4.6, RM 5.6, and RM 6.7, and the western nearshore zone between RM 8 and 9.2 (**Figure 2.1-18a**). The highest subsurface concentrations of zinc were found in the western nearshore zone at RM 9-9.2 and in Swan Island Lagoon (**Figure 1.2-18b**). Zinc concentrations are generally similar in the surface sediments and subsurface sediments within the Study Area.

Tributyltin Ion
The highest concentrations of tributyltin were reported in surface sediment near the eastern nearshore zone at RM 3.7, RM 7.5, and in Swan Island Lagoon (**Figure 2.1-19a**). The highest subsurface concentrations of tributyltin are found in the eastern nearshore zone between RM 7 and RM 8, and in Swan Island Lagoon (**Figure 2.1-19b**). Concentrations are generally higher in subsurface than surface sediments within the Site, pointing to primarily historical inputs to the Study Area.

1.2.3.3 Surface Water

Concentrations of contaminants in surface water samples varied both spatially and with river flow. Surface water sample locations with the highest reported contaminant concentrations are as follows:

River Mile	River Location	Sample ID	Contaminants
MC	Transect	W027	PCDD/Fs, aldrin, copper
2	East	W001	PCBs, DDx
	West	W002	chlordanes
	Transect	W025	PCBs, BEHP, aldrin
3	International Slip	W004	PCBs
	East	W028	PCBs

River Mile	River Location	Sample ID	Contaminants
4	West	W029	BEHP, chlordanes
5	East	W030	PCBs, DDx, chlordanes
6	East	W013, W014, W032	PCBs, PCDD/Fs
	West	W015, W031	PCBS, PCDD/Fs, DDx, PAHs, chlordanes, aldrin, dieldrin, copper
	Transect	W011	PCDD/Fs, BEHP, aldrin
7	West	W016, W033	PCBs, PCDD/Fs, DDx
8	West	W019, W036	PCBs, PAHs, BEHP
9	West	W022, W037	DDx, zinc
11	Transect	W023	PCDD/Fs, chlordanes, copper
16	Transect	W024	BEHP, copper

RM 7E, RM 8E, RM 9E, and RM 10 were not sampled.
BEHP - bis(2-ethylhexyl) phthalate

Concentrations of contaminants in surface water within the Study Area are generally higher than those entering the upstream limit of the Study Area (W024 at RM 16) under all flow conditions. The highest contaminant concentrations in surface water within the Site were found near known sources. At the downstream end of the Study Area, RM 2 (W001, W002, W025) and Multnomah Channel (W027), concentrations of total PCBs, dioxin/furans, DDx, BEHP, chlordanes, and aldrin in surface water are greater than concentrations entering the Study Area that indicate contamination from Portland Harbor is being transported downstream to the Columbia River.

1.2.3.4 Groundwater

Figure 1.2-20a through Figure 1.2-20h and **Figure 1.2-21** (inset of the Doane Lake area) show the nature and extent of known contaminated groundwater plumes currently or potentially discharging to the river. Cleanup of contaminated groundwater is being managed by DEQ under an MOU with EPA (see 1.2.2.2, above). The following provides a discussion of the groundwater plumes presented in **Figures 1.2-20a through 1.2-20h** and **1.2-21.** Additional information on these sites is available in DEQ's ECSI database.

East Side of Willamette River

RM 2
Evraz Oregon Steel Mill (ESCI Site ID 141) –Contaminants are manganese and arsenic.

RM 3.5
Time Oil (ECSI Site ID 170) – Contaminants are pentachlorophenol, arsenic, gasoline- and diesel-range hydrocarbons.

Premier Edible Oil (ECSI Site ID 2013) – Contaminants are TPH (diesel-range hydrocarbons), manganese, and arsenic.

Schnitzer Steel Industries (ECSI Site ID 2355) – A halogenated VOC plume is known to be discharging to the river. Contaminants include cis-1,2-dichloroethene (cis-1,2-DCE), tetrachloroethene (PCE), and trichloroethene (TCE).

RM 4.5
Terminal 4 Slip 3 (ECSI Site ID 272) – Contaminants include TPH (diesel-range hydrocarbons).

RM 6
McCormick & Baxter Creosote Co. (ECSI Site ID 74) – Contaminants include pentachlorophenol, PAHs, arsenic, chromium, copper, and zinc.

RM 11
Tarr Oil (ECSI Site ID 1139) – A halogenated VOC plume is not known to be releasing to the river. Contaminants include cis-1,2-DCE, PCE, TCE, and vinyl chloride.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – A TPH plume is located onsite and has released to the river. Contaminants include light non-aqueous phase liquids (LNAPL), diesel-range hydrocarbons, residual-range hydrocarbons, and gasoline-range hydrocarbons.

RM 5
BP Arco Bulk Terminal (ECSI Site ID 1528) – A TPH plume has discharged to the river. Contaminants include TPH (gasoline-range and diesel-range hydrocarbons) and LNAPL, and the plume extends under the adjacent downstream property.

Exxon Mobil Bulk Terminal (ECSI Site ID 137) – A TPH plume has discharged to the river. Contaminants include gasoline- and diesel-range hydrocarbons.

RM 5.5
Foss Maritime/Brix Marine (ECSI Site ID 2364) – TPH releases from underground storage tanks (USTs) have been identified onsite. Contaminants include gasoline- and diesel-range hydrocarbons.

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Goundwater contamination associated with historical MGP waste is known to be discharging to the river. Contaminants detected in groundwater include PAHs, SVOCs, VOCs (e.g., BTEX), cyanide, sulfide, sulfate and carbon disulfide, ammonia, and metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc). Gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons and total petroleum hydrocarbon fractions are being added to the groundwater monitoring program.

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – A chlorinated VOC plume as well as groundwater plumes associated with historical MGP waste and pesticide plumes from Rhone Poulenc are known to discharge to the river. Contaminants include petroleum-related and chlorinated VOCs (benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,1-dichloroethene, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride), PAHs, gasoline-range, diesel-range, and residual-range hydrocarbons, cyanide, metals (arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, thallium, vanadium, and zinc), 2,4,5-trichlorophenoxyacetic acid (2,4,5-TP), and 2-(2,4-Dichlorophenoxy)propionic acid (2,4-DP-p).

RM 7
Rhone Poulenc (ECSI Site ID 155) – Known releases of organochlorine insecticides and herbicides, including pentachlorophenol (PCP), 2,4-DP, Bromoxynil, 4(2,4-dichloropenoxy)butyric acid (2,4-DB), 2-methyl-4-chlorophenoxyacetic (MCPA), methylchlorophenoxypropionic acid (MCPP), 4-(4-chloro-2-methylphenoxy)butanoic acid (MCPB), 2,4,5-trichlorophenoxyacetic acid [2,4,5-T], 2,4-dichlorophenoxyacetic acid (2,4-D), DDT, Endrin, Heptachlor, sodium chlorate, sodium arsenate, 2,4,5-TP, aldrin, dieldrin, chlordanes, and 2,4-DP-p have occurred at the site.

Contaminants migrating in groundwater include VOCs, and herbicides. Contaminants infiltrating City Outfall 22B include: SVOCs (2,4,6-trichlorophenol, 2,4-dichlorophenol, 2-methylphenol, pentachlorophenol, and naphthalene), insecticides (aldrin, alpha-chlordane, dieldrin, gamma-chlordane, heptachlor epoxide, hexachlorobenzene, DDD, DDE, and DDT), dioxin/furans (2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD]) and metals (aluminum, boron, molybdenum, thallium, arsenic, barium, iron, manganese) (ODEQ 2013).

Kinder Morgan Pump Station (ECSI Site ID 2104) – A TPH plume has been identified at the pump station.

Arkema (ECSI Site ID 398) – Contaminants detected in groundwater at the site include, but are not limited to, DDT and its metabolites DDD and DDE (DDx) and VOCs (chlorobenzene, chloroform, PCE, TCE and benzene), perchlorate and hexavalent chromium.

RM 8

Kinder Morgan Willbridge Bulk Terminal (ECSI Site ID 160) – A TPH plume is not known to be currently discharging to the river. Contaminants include gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and arsenic.

Chevron and Unocal Willbridge Bulk Terminal (ECSI Site IDs 25 & 177) – A TPH plume located onsite has discharged to the river. Contaminants include LNAPL, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and metals (arsenic and manganese).

Chevron Asphalt Plant (ECSI Site ID 1281) – Free product consisting of relatively immobile asphalt-related petroleum has been noted on site. Contaminants include TPH (diesel-range and gasoline-range hydrocarbons), arsenic, BTEX and naphthalene.

RM 9

Gunderson (ECSI Site ID 1155) –There is a chlorinated VOC plume (1,1-DCE, 1,1,1-trichloroethane [1,1,1-TCA], PCE, TCE and vinyl chloride) near the downstream end of the Gunderson property. In addition, there is a PAH groundwater plume located between the Equilon (Shell Terminal) pipeline gasoline release and the Equilon dock at Gunderson.

Christensen Oil (ECSI Site ID 2426) – A TPH (Stoddard solvent) plume is located onsite.

Univar (ECSI Site ID 330) – A VOC plume is located onsite. Contaminants include 1,1-dichloroethane (DCA), 1,1-DCE, cis-1,2-DCE, methylene chloride, PCE, toluene, 1,1,1-TCA, TCE, vinyl chloride, and xylenes.

Galvanizers Inc. (ECSI Site ID 1196) – A zinc plume is located at this site.

RM 10

Sulzer Pump (ECSI Site ID 1235) – TPH, PAH, and VOC plumes from UST and waste oil UST releases exist at this site.

RM 11.5
Centennial Mills (ECSI Site ID 5136) – A TPH (diesel-range hydrocarbons) plume is located at this site. The plume is not known to discharge to the river, but may be infiltrating the Tanner Creek sewer line near the river.

1.2.3.5 Riverbanks

Identification of contaminated banks is being managed by DEQ under an MOU with EPA. The following provides a discussion of the known contaminated banks. Additional information on these sites is available in DEQ's ECSI database.

East Side of Willamette River

RM 2
Evraz Oregon Steel Mill (ECSI Site ID 141) – Contaminants present in the riverbank includes PCBs and metals (arsenic, cadmium, chromium, copper, lead, manganese, and zinc).

RM 3.5
Schnitzer Steel Industries (ECSI Site ID 2355) – Results of soils samples collected under the docks along the south shore of the International Slip indicate that contaminants are PCBs and dioxins.

RM 5.5
MarCom South (ECSI Site ID 2350) – Further investigation of the nature and extent of contamination in the bank was conducted in 2012. Contaminants are PAHs and metals (arsenic, cadmium, chromium, copper, zinc).

RM 7
Willamette Cove (ECSI Site ID 2363) - Riverbank contaminants are PCBs, dioxins/furans, metals (lead, mercury, nickel, and copper), and PAHs.

RM 8.5
Swan Island Shipyard (ECSI Site ID 271) – Recent sampling results for OU1 indicate that contaminants include metals (arsenic, cadmium, chromium, copper, lead, mercury, and zinc), PAHs, PCBs, and tributyltin. Contaminants in riverbank soils in OU5 include metals (arsenic, copper, lead, and zinc), PAHs, and PCBs.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – Contaminants are petroleum constituents (BTEXs and PAHs) and metals (arsenic and lead).

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Contamination associated with historical MGP waste are known to be located in the riverbank. Contaminants include PAHs, gasoline-

range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, cyanide, and metals (zinc).

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – Contamination associated with historical MGP waste is known to be present in the northern portion of the Siltronic riverbank. Riverbank contaminants include PAHs, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbon and cyanide and metals (zinc).

BNSF Railroad Bridge – Contamination associated with pesticide and herbicide releases from Rhone Poulenc and Arkema are known to be present in the riverbank below and adjacent to the BNSF railroad bridge. Riverbank contaminants include dioxin/furans, metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, zinc, insecticides (DDD, DDE, DDT, aldrin, alpha-hexachlorocyclohexane [alpha-BHC], alpha-chlordane, beta-BHC, cis-nonachlor, delta-BHC, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, gamma-BHC, gamma-chlordane heptachlor, heptachlor epoxide, hexachlorobutadiene, methoxychlor, mirex, oxychlordane, and trans-nonachlor), PCBs, SVOCs (acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzoic acid, benzyl alcohol, bis (2-ethylhexyl)phthalate, butylbenzylphthalate, chrysene, bibenzo(a,h)anthracene, dimethylphthalate, di-n-butylphthalate, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene). (AMEC 2011).

RM 7
Arkema (ECSI Site ID 398) –Riverbank contaminants include DDT, dioxin/furans, PCBs, and metals (chromium and lead).

RM 9
Gunderson (ECSI Site ID 1155) –Contaminants include metals (lead, nickel, and zinc), and PCBs.

1.2.4 Contaminant Fate and Transport

Most of the sediment contamination at the Site is associated with known or suspected historical sources and practices. Ongoing sources of contamination include contaminated groundwater plumes, riverbank soils, stormwater and upstream surface water. The distribution of contaminants in sediments in several nearshore areas appears to reflect more significant historical lateral inputs. Persistent contaminants (particularly PCBs and dioxin/furans) from sediments and surface water bioaccumulate in progressively higher trophic levels within the food chain.

Internal contaminant fate and transport processes are those processes that affect the fate, transport and redistribution of contaminants within the Study Area. The major internal fate and transport processes are:

- Erosion from the sediment bed
- Deposition to the sediment bed
- Dissolved flux from the sediment bed (porewater exchange)
- Groundwater advection
- Degradation (for some contaminants)
- Volatilization
- Downstream transport of either particulate-bound or dissolved phase contaminants

These processes interact to create complex patterns of contaminant redistribution that vary over space, time, and by contaminant. Empirical estimates of contaminant loading associated with internal and external contaminant sources were developed during the RI. External sources include upstream loading (via surface water and sediment bedload), "lateral" external loading such as stormwater runoff permitted discharges (point-source, non-stormwater), upland groundwater (contaminant plume transport to river), atmospheric deposition (to the river surface), direct upland soil and riverbank erosion, otherwise uncontaminated groundwater advection through contaminated subsurface sediments (chemical partitioning from subsurface sediment to porewater and advection to the surface sediment interval), and overwater releases. Internal sources include surface sediment loading to the surface water via sediment erosion (resuspension) and sediment porewater exchange (chemical partitioning from surface sediment to porewater and advection to surface water), as well as sinks. **Figures 1.2-22a** through **1.2-22c** provides a visual summary of currently known or suspected contaminant source loads within and exiting from the Site for three representative contaminants: total PCBs, benzo(a)pyrene, and DDE.

Elevated contaminant concentrations in the Study Area are typically associated with areas near currently known or likely historical and/or existing sources. Although the highest sediment contaminant concentrations are generally found in nearshore areas, higher concentrations are also found in the higher-energy portion of the channel in the middle of the Study Area (RM 5 to 7). This may reflect past or current dispersal of material away from nearshore source areas. Throughout the Study Area, contaminant concentrations are generally higher in subsurface sediments than in surface sediments, indicating both higher historical contaminant inputs and improving sediment quality over time. Localized exceptions to the pattern of higher subsurface sediment concentrations exist in a few areas for some contaminants, likely reflecting more recent

releases and/or disturbances of bedded sediments. Also, the depth of subsurface contamination is generally greater in nearshore areas as compared to the navigation channel.

Areas with elevated contaminant concentrations in surface sediments generally correspond to areas of elevated subsurface sediment contaminant concentrations, particularly in nearshore areas. Areas where only surface or subsurface sediments exhibited elevated concentrations of contaminants point to spatially and temporally variable inputs and sources, or to different influences from sediment transport mechanisms. The PCB distributions in areas of elevated PCB concentrations are generally distinct from those in surrounding areas of lower PCB concentrations. Within areas of elevated PCB concentrations, the PCB patterns in surface and subsurface sediment, sediment traps, and in the particulate portion of the surface water samples are often similar. A similar pattern and similar composition across media was observed to a lesser degree for PAHs, but was less apparent for dioxins/furans or DDx compounds.

Most areas of elevated contaminant concentration in bedded sediment are located in relatively stable nearshore areas, and large-scale downstream migration/dispersal of concentrated contaminants from these areas is not indicated by the bedded sediment data. Much larger historical direct discharges from upland and overwater sources, rather than reworking of bedded sediments, are believed to have produced some of the observed patterns (e.g., elevated levels in subsurface sediments downstream of the source areas). Limited ongoing downstream dispersal of contaminants in sediments is suggested based on bedded sediment concentration gradients downstream of areas with elevated sediment concentrations.

Patterns of contamination in bedded surface sediment indicate some redistribution of contaminants over time from past source areas, but this is limited by burial of much of the source area contamination as indicated by higher subsurface sediment concentrations in these areas. Periodic erosion may temporarily expose buried contamination.

Based on results of surface water data collected during the RI, resuspension and/or dissolved phase flux from the sediment bed are contributing to contaminant concentrations in surface water, particularly in quiescent areas where surface water mixing and dilution is minimal. Loading estimates presented in **Figures 1.2-22a** through **1.2-22c** are consistent with this concept, indicating the mass flux of contaminants exiting the downstream end of the Study Area in surface water, either directly to the Columbia River or via Multnomah Channel, is greater than the flux entering the Study Area.

Contaminant concentrations in stormwater entering the Study Area are generally greater than concentrations associated with upstream surface water. However, from a loading perspective, lateral contaminated loads associated with upland sources are comparable to upstream loads for certain contaminants.

Groundwater plume discharge to surface water has been observed in several areas. Dissolved phase flux from surface sediments to the water column has been inferred from RI data.

Finally, empirical tissue contaminant data and food web modeling indicate that persistent contaminants (particularly PCBs and dioxin/furans) in sediments and surface water can bioaccumulate in aquatic species tissue.

The CSM integrates the information gathered to date to provide a coherent hypothesis of the Site fate and transport. **Figure 1.2-23** provides a simplified visual summary of this hypothesis, including contaminant interactions with human and ecological receptors.

1.2.5 Baseline Risk Assessment

This section presents a summary of the results of the baseline human health and ecological risk assessments (BHHRA and BERA). These assessments are presented in Appendix F and Appendix G of the RI report.

1.2.5.1 Baseline Human Health Risk Assessment

The BHHRA presents an analysis of the potential for effects associated with both current and potential future human exposures at Portland Harbor. Potential exposure to contaminants found in environmental media and biota was evaluated for various occupational and recreational uses of the river, as well as recreational, subsistence, and traditional and ceremonial tribal consumption of fish caught within the Portland Harbor site. Additionally, because of the persistent and bioaccumulative nature of many of the contaminants found in sediment, infant consumption of human breast milk was also quantitatively evaluated.

Consistent with EPA policy, the BHHRA evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. In addition, estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. **Figure 1.2-24** presents the CSM for the BHHRA and **Table 1.2-2** provides a list of chemicals potentially posing unacceptable risks for human health.

The major findings of the BHHRA are:

- Estimated cancer risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment and surface water. Risks and noncancer hazards from fish and shellfish consumption exceed the EPA point of departure for cancer risk of 1×10^{-4} and target hazard index (HI) of 1 when evaluated on a harbor-wide basis, and when evaluated on the smaller spatial scale by river mile.

- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4×10^{-3} and 1×10^{-2} for recreational and subsistence fishers, respectively.

- Evaluated on a river mile scale, it is only at RM 5 that RME risk estimates from consumption of resident fish is less than 1×10^{-4}.

- Noncancer hazard estimates for consumption of resident fish species are greater than 1 at all river miles. Based on a harbor-wide evaluation of noncancer risk, the estimated RME HI is 300 and 1,000 for recreational and subsistence fisher, respectively. The highest hazard estimates for recreational fishers are at RM 4, RM 7, RM 11, and in Swan Island Lagoon.

  The highest noncancer hazards are associated with nursing infants of mothers, who consume resident fish from Portland Harbor. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for breastfed infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME HI for tribal consumers of migratory and resident fish is 600 assuming fillet-only consumption, and 800 assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers, who consume fish, are 8,000 and 9,000 respectively, assuming maternal consumption of fillet or whole-body fish.

- PCBs are the primary contributor to risk from fish consumption harbor-wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The greatest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from Portland Harbor. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it is not clear to what degree contamination in Portland Harbor contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific disease, and the cancer estimates represent upper-bound values, and the EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.

1.2.5.2 Baseline Ecological Risk Assessment

The BERA presents an evaluation of risks to aquatic and aquatic-dependent species within the Study Area in the absence of any actions to control or mitigate contaminant releases. The overall process used for the BERA was based on the guidance provided in

the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final* (EPA 1997c) and followed the approach documented in numerous interim deliverables as well as discussions, directives, and agreements with the LWG, EPA and its federal, state, and tribal partners. **Figure 1.2-25** presents the CSM for the BERA and **Table 1.2-3** provides a list of contaminants of potential concern (COPCs) posing potentially unacceptable ecological risks within the Portland Harbor Study Area. A list of chemicals identified as most likely to be contaminants of ecological significance is provided in **Table 1.2-4**.

The following presents the primary conclusions of the BERA.

- In total, 93 contaminants (as individual contaminants, sums, or totals)[5] with HQ ≥ 1.0 pose potentially unacceptable ecological risk. Differences in the specific toxicity reference values (TRVs) used in different lines of evidence (LOEs) for total PCBs (e.g., total PCBs versus specific Aroclor mixtures), total DDx, and total PAHs, all of which describe individual contaminants or a group of multiple but related individual chemical compounds, can result in different counts of the number of contaminants posing potentially unacceptable risk. The list of contaminants posing potentially unacceptable risks can be condensed if individual PCB, DDx and PAH compounds or groups are condensed into three comprehensive groups: total PCBs, total DDx, and total PAHs. Doing so reduces the number of contaminants with HQ ≥ 1.0 posing potentially unacceptable risks to 66.

- Risks to benthic invertebrates are clustered in 17 benthic areas of concern (AOCs).

- Sediment and TZW samples with the highest HQs for many contaminants also tend to be clustered in areas with the greatest benthic invertebrate toxicity.

- The COPCs in sediment that are most commonly spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs and DDx compounds.

- Not all COPCs posing potentially unacceptable risk have equal ecological significance. The most ecologically significant COPCs (i.e., contaminants of primary ecological significance) are PCBs, PAHs, dioxins and furans (as toxic equivalent [TEQ]), and DDT and its metabolites.

[5] The five chemicals or chemical groups with concentrations that exceeded only the sediment probable effects concentration (PEC) and/or probable effects level (PEL) (i.e., chemicals that were not identified as COPCs for other benthic invertebrate LOEs: Aroclor 1254, chlordane [cis and trans], gamma- hexachlorocyclohexane [HCH] [Lindane], heptachlor epoxide, and total chlordane), ammonia and sulfide (which are conventional parameters), and residual-range hydrocarbons that had concentrations that exceeded only the total petroleum hydrocarbons [TPH] SQGs) are not included in this count.

- The list of ecologically significant COPCs is not intended to suggest that other contaminants in the Study Area do not also present potentially unacceptable risk.

- The contaminants identified as posing potentially unacceptable risk in the largest numbers of LOEs are (in decreasing frequency of occurrence) total PCBs, copper, total DDx, lead, tributyltin (TBT), zinc, total TEQ, PCB TEQ, benzo(a)pyrene, cadmium, 4,4′-DDT, dioxin/furan TEQ, bis(2-ethylhexyl) phthalate, naphthalene, and benzo(a)anthracene. The remaining 78 contaminants posing potentially unacceptable risk were identified as posing potentially unacceptable risk by three or fewer LOEs.

- Of the three groups of contaminants (i.e., total PAHs, total PCBs, total DDx) with the greatest areal extent of HQs ≥ 1.0 in the Study Area, PAH and DDx risks are largely limited to benthic invertebrates and other sediment-associated receptors. PCBs tend to pose their largest ecological risks to mammals and birds.

- The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as total TEQ, poses the potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey. The PCB TEQ fraction of the total TEQ is responsible for the majority of total TEQ exposure, but the total dioxin/furan TEQ fraction also exceeds its TRV in some locations of the Study Area.

1.3 FS DATABASE DESCRIPTION

This section describes the FS database that contains the sediment data used in the alternatives development and evaluations in this FS. The source of the sediment data within the FS database is the Site Characterization and Risk Assessment (SCRA) database used for evaluations in the RI Report (RI citation). However, the SCRA database did not use consistent summing rules as were used in the baseline risk assessment (BRA). To allow for evaluations of risk reduction based on various alternatives presented in this report, it was necessary to ensure that the data were treated in a manner consistent with the BRA. Data selection, evaluation, summation rules, and other rules and procedures for the FS database are described in Appendix A. The FS database only includes sediment data and does not contain porewater, surface water, TZW, or biota/tissue data; those data are retained in the SCRA database although they may be used for analysis in this FS.

For the RI and FS, a date of May 1, 1997, was used to define the initiation of the sediment dataset to follow the last major flood of the lower Willamette River in the winter of 1996. The SCRA database includes data collected through July 19, 2010. However, the following additional sediment data was added to the FS database:

- Additional updates to the SCRA database posted to the LWG's portal through February 4, 2011

- Gasco Engineering Evaluation/Cost Analysis (EE/CA) data as provided by Anchor QEA in 2013 and meeting the FS sediment database protocols described in Appendix A

- Arkema EE/CA data as provided by Integral in May 2014 and meeting the FS sediment database protocols described in Appendix A

As noted in Section 1.2.2.3, the RM11E Group entered into an AOC to collect additional data (to include sediment, riverbank soil, porewater, and groundwater data) in support of preliminary remedial design activities. While the sediment data was not included within the FS database due to timing, all the data will be available in the Administrative Record for use during remedial design.

The SCRA database or the FS database may be used for some depictions or evaluations in this FS. Unless otherwise noted, the FS database was used for evaluations of sediment in this report.

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